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A STUDY OF THE THERMAL INITIATION, COOKOFF, OF M30 PROPELLANTS

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June 1978

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
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A study has been made of the thermal stability of the triple-base propellant M30. The apparatus employed applies the test specimen for a controlled time interval to a heated copper block with a force adequate to maintain good thermal contact. A GO-NO GO test procedure was followed over the temperature range 200 to 260°C. A lower contact time limit was observed below which ignition never occurred. A high contact time limit was also observed above which ignition always occurred. Between these limits, which become narrower with increasing

ABSTRACT (Cont'd)

temperature, ignition was variably observed. Contact geomtery and contact pressure were also studied. The latter was found to have a significant effect on time to ignition of a single grain with the time to ignition and the variability of observation increasing as contact pressure was decreased. The variation in time to cookoff with temperature was found to follow an Arrhenius relationship. The high limit data gave $A = 5.5 \times 10^{16}$ and $E = 39.8$ kcal/mole. The low limit data gave $A = 9.8 \times 10^{15}$ and $E = 37.8$ kcal/mole. These relationships give a reasonably good match to experimental cartridge case cookoff data

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

I. INTRODUCTION

Ammunition storage compartments remote from the crew compartment are being designed for developmental armored vehicles. The objective is to lower the vulnerability of the vehicle by reducing the contribution from the ammunition. A problem exists with this approach in that a fire which results from a single cartridge being hit in an encounter may lead to thermal initiation or cookoff of the remaining ammunition.

As part of the Ballistic Research Laboratory (BRL) task to improve the ammunition storage compartment in tanks, a problem arose in reconciling conflicting cookoff test results. A series of tests were conducted by Frey[1] (BRL)in which rounds were wrapped with heating wire and heated at various rates and the time to explosion and wall temperature at explosion were measured. The results were not in agreement with those from work done at Picatinny Arsenal[2] (PTA) in which a grain of propellant was placed on its side on a hot surface at a known temperature and the time to ignition measured. The times to ignition were much longer for the latter tests.

In order to resolve this discrepancy, a proposal was made to study the thermal initiation of M30 propellant by another technique. Previous work by Strittmater and Holmes[3] employed a hot-plate method to study cookoff and relative thermal sensitivity of propellants. A large copper block was heated to a known temperature and the propellant samples were attached to one end of an electrically-triggered, spring-loaded arm. When the arm was triggered, the sample was rapidly placed in contact with the hot copper block and kept in good surface contact for a preset time. Then,when the spring-loaded arm was electrically released, the sample either continued to burn to completion or extinguished. Results were reported as a visual observation of the GO - NO GO type with respect to sustained combustion after liftoff of the arm. The tests described in this report were conducted with an improved version of the Strittmater-Holmes apparatus.

II. EXPERIMENTAL METHODS

The original instrumentation used by Strittmater and Holmes[3] was modified to the extent that more precise temperature and time control was possible. The temperature sensor was an iron/constantan thermo-

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1. *Robert B. Frey, et al, "Pressure Measurements in Lightly Confined M456 Cartridge Cases After Primer and Cookoff Ignition", Ballistic Research Laboratory Memorandum Report No. 2764, June 1977* (AD #B020522L)
2. *Sidney Bernstein, Picatinny Arsenal, private communication to R.E. Prenatt, Ballistic Modeling Division, Ballistic Research Laboratory.*
3. *Richard C. Strittmater and Hughes E. Holmes, "Hot Plate Flammability Tests", Ballistic Research Laboratories Memorandum Report No. 2292, May 1973.* (AD #762149)

couple inserted into the copper block just under the surface and monitored by a Model 1000 Honeywell Differential Voltmeter. The readout scale was adjusted so that the temperature could be read ± 0.1 °C. A similar thermocouple was used as a control in conjunction with a Model 200 F&M Power Proportioning Temperature Controller which was adjusted so that the temperature of the copper block would not vary more than ± 0.5 °C. A Tektronix Type 162 Waveform Generator was used to control the time pulse that initiated the lifting of the sample arm from the hot block; the time could be varied from 0.1 ms to 10 s. The actual time was read on a Model 361-R TSI Universal Counter. A photograph of the instrumentation and hot plate apparatus is shown in Figure 1.

The top of the copper block was covered with silver solder to ensure a surface less prone to oxidation. It was periodically necessary (after 8-12 runs) to clean the surface of accumulated decomposition products. This prevented the forming of a carbonaceous residue which would act as an insulating layer between the sample and the copper block. The force exerted by the spring-arm is given in Figure 2 which shows the force as a function of the fraction of spring compression. The spring was 50-to 75-percent compressed during a typical run (forces between 8 and 10 newtons).

A baffle was placed around the hot plate so that the sample and heated surface would be relatively free from convective cooling by air currents. The studies were always carried out in a laboratory fume hood. There was no confinement of the gaseous products given off during combustion.

The propellant chosen for this study was M30, a triple-base formulation used in tank rounds and for other BRL tests of vented ammunition compartments. Propellant samples were prepared by cutting standard 7-perforation grains to 6.35 mm (0.25 inch) in length and preparing the ends to ensure complete contact over the whole surface area. This consisted of making sure the end surfaces were as parallel and smooth as possible and that the perforations were cleaned of any particulate matter.

The majority of test samples were 6.35 mm (0.25 inch) in diameter, although some tests were performed on 2.54-mm (0.1-inch) diameter samples. Propellant descriptions are given in Table I.

Table I. Propellant Descriptions

Propellant	Lot	Diameter	Web
M30	PA-63557	6.35 mm (0.25 inch)	1.17 mm (0.046 inch)
M30	RAD-E31	2.54 mm (0.10 inch)	0.38 mm (0.015 inch)

The samples were attached to the spring-loaded arm with double-stick tape. The standard mode was with the grain vertical so that the flat end was applied to the hot copper block. In some cases, the grain was attached horizontally so that the curved outer surface was applied.

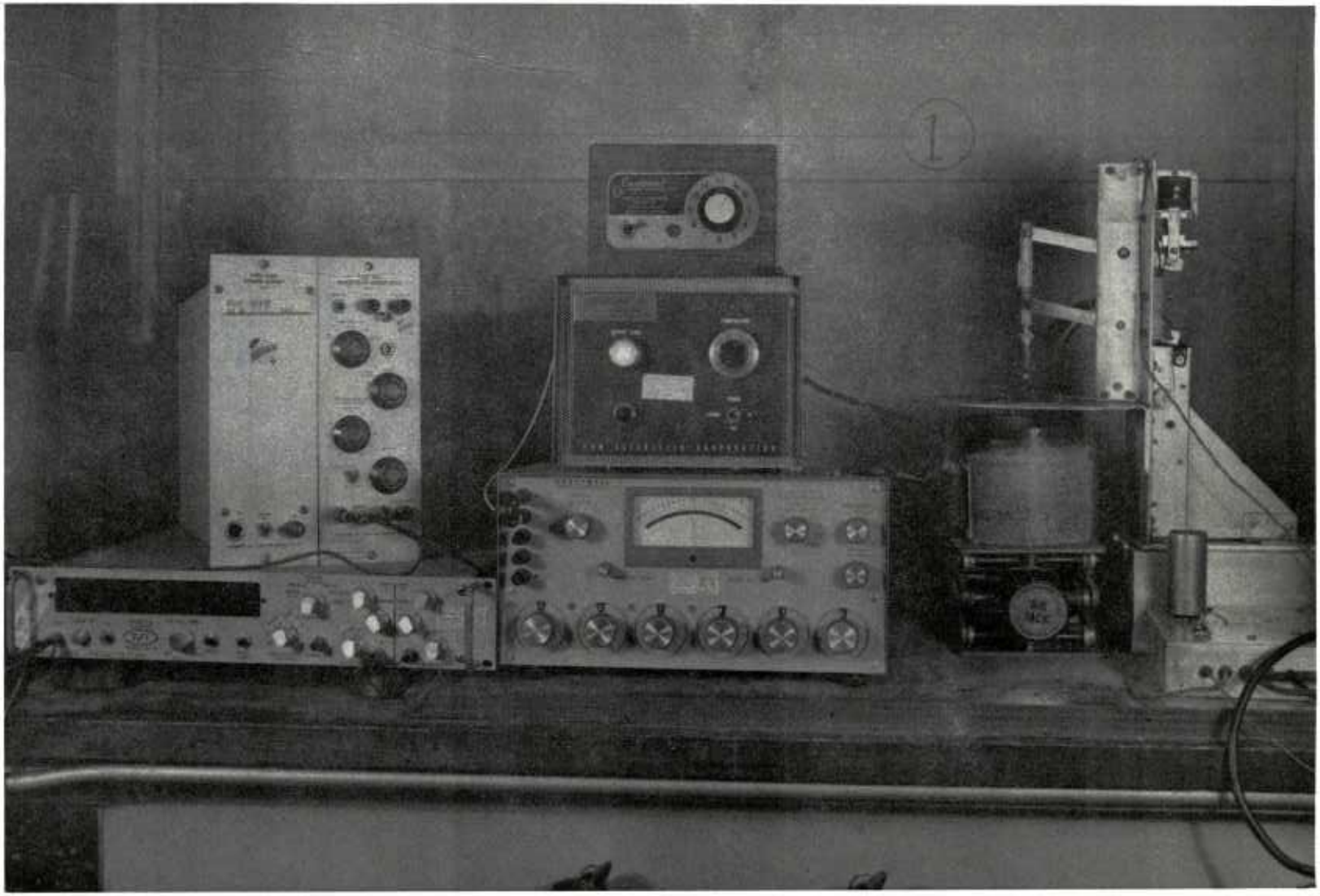

Figure 1. Photograph of Instrumentation and Hot Plate Apparatus

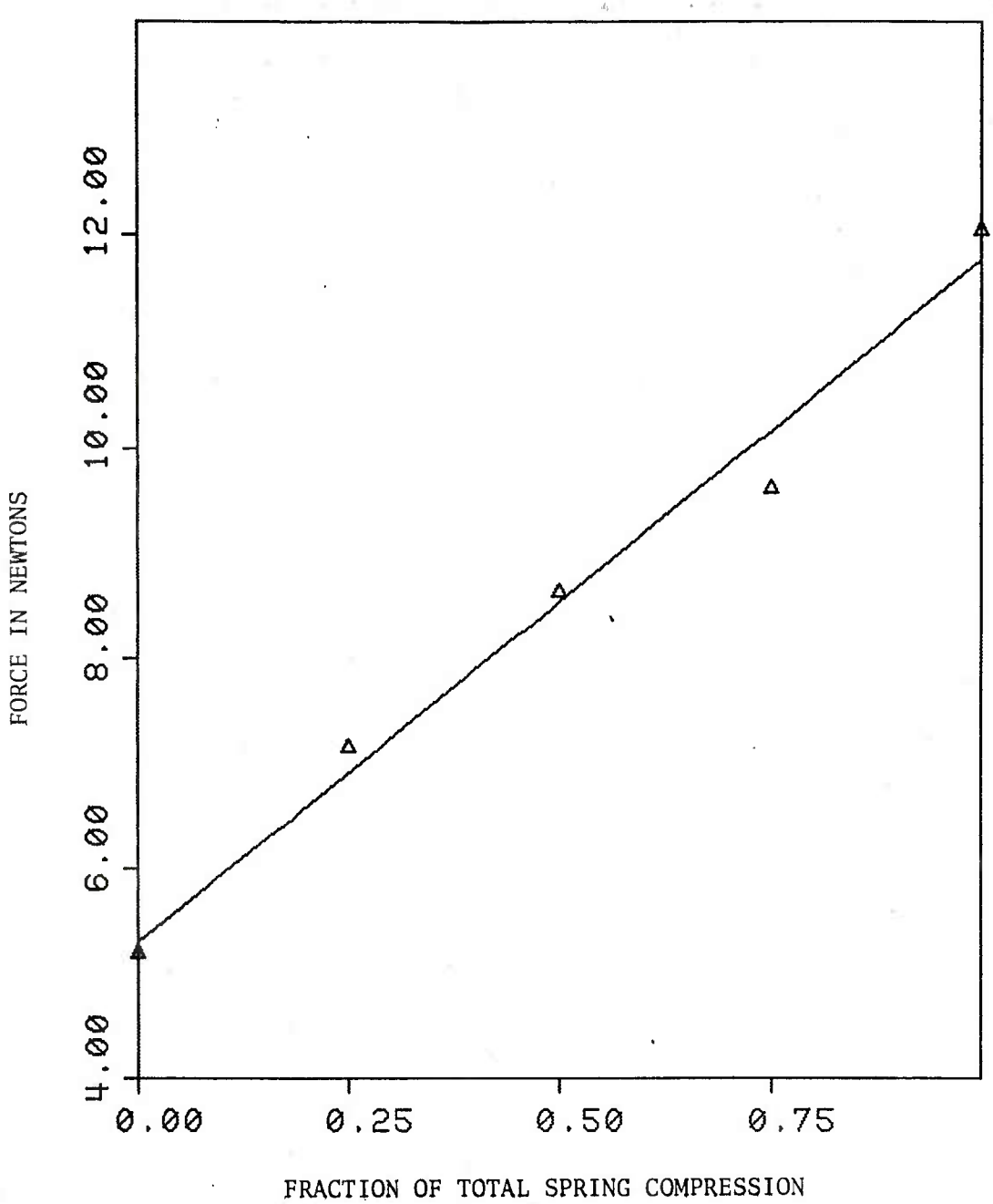

Figure 2. Plot of Force versus Spring Compression

A primary question was the effect of the contact pressure between a hot surface and a propellant grain on the ignition limits of the propellant. A series of tests was run in which the sample was simply laid on the hot surface and the time to ignition measured with a stop watch. This technique was analogous to that used by Picatinny Arsenal. Test configurations are listed in Table II.

Table II. Test Configurations

Configuration No.	Force Applied	Grain Position
1	Standard	Vertical
2	Standard	Horizontal
3	None	Vertical
4	None	Horizontal

III. RESULTS AND DISCUSSION

The results for the 6.35-mm (0.25-in.) diameter grain in a vertical position are listed in Tables A-I through A-VI, in Appendix A, as a simple GO - NO GO observation for each sample as a function of block temperature and contact time. Each sample is referenced to a set of notes, Table III, that gives a more detailed description of the reactions observed.

Table III. Explanation of Notes for Tables A-I - A-X

1A	No sustained combustion and no observable reactions during contact.
1B	No sustained combustion but visual evidence of reaction (smoke, evolution of gases) during contact.
1C	No sustained combustion but sample undergoes thermal degradation with dimensional changes during contact.
1D	Ignited while in contact but no sustained combustion after liftoff.
2A	Sustained combustion after loss of surface contact - relatively slow fizz burning.
2B	Sustained combustion after loss of surface contact - relatively fast with flame.

Only those samples meeting observations 2A or 2B (sustained combustion) are listed as GO in the tables.

A. Effect of Temperature

The results are given for 10-degree intervals from 210 - 260°C. In runs at 200 and 190°C, ignition did not occur. A gradual softening and mushrooming resulted, eventually forming a "putty-like", amorphous mass. Wisps of smoke occasionally were seen, however, indicating that chemical decomposition was taking place. At 200°C, this process took between 10 and 12 minutes and at 190°C, it took 15 minutes or longer.

From the data in Tables A-I through A-VI a high and low limit were selected. The high limit was that time above which one could always expect sustained combustion and the low limit was that time below which sustained combustion did not occur. A summary of the higher and lower limits is given in Table IV.

Table IV. Summary of Cookoff Data for M30 Propellant (Lot PA-63557)

Configuration	Temp (°C)	Time (s) Lower Limit	Higher Limit
1	260	0.260	0.378
1	250	0.574	0.621
1	240	1.538	2.329
1	230	3.422	4.111
1	220	6.257	7.045
1	210	9.400	18.256
2	250	0.585	0.670
2	240	1.956	2.015

The relationship between these limits is shown graphically in Figure 3 where the high and low limit times are plotted versus temperature. This clearly shows the increasing time spread during which sustained combustion takes place as temperature is decreased. This is to be expected, for, as the temperature of the hot surface is decreased, the thermal energy imparted to the sample is lower . Slower thermal decomposition and self-heating of the sample result. Therefore, convective and radiative energy losses from the sample become more important.

The data in Figure 3 appear to follow an exponential relationship with temperature. Such a relationship would be expected if the surface temperature of the sample is a major controlling factor in determining the time to ignition. This is supported by Arrhenius plots where the log of the reciprocal of the limit time was plotted versus the reciprocal of the block surface temperature. These are shown in Figures 4 and 5 for the high and low limit data respectively. Reasonable first order fits result

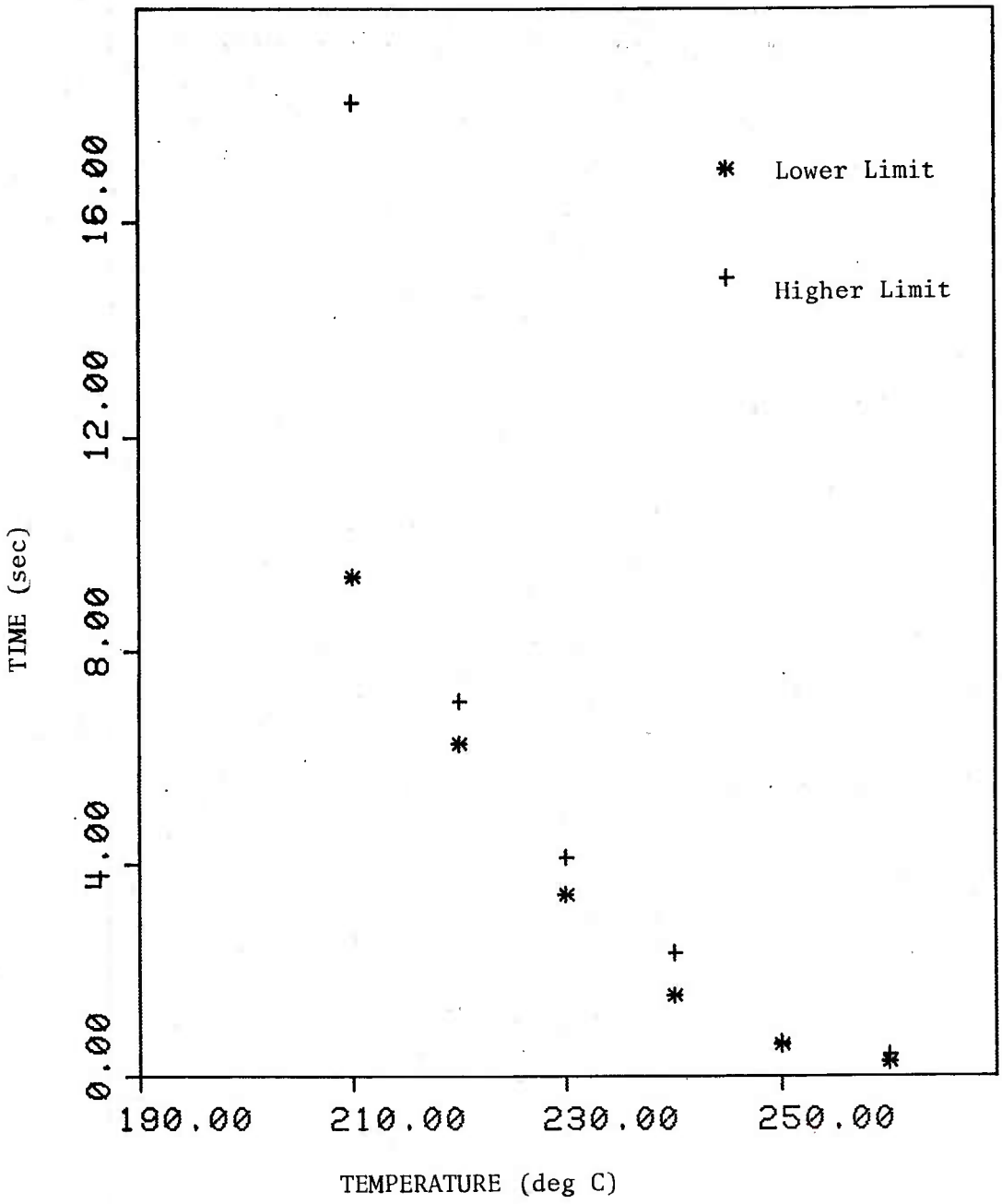

Figure 3. Graphical Summary of Test Configuration 1 Higher and Lower Limit Data

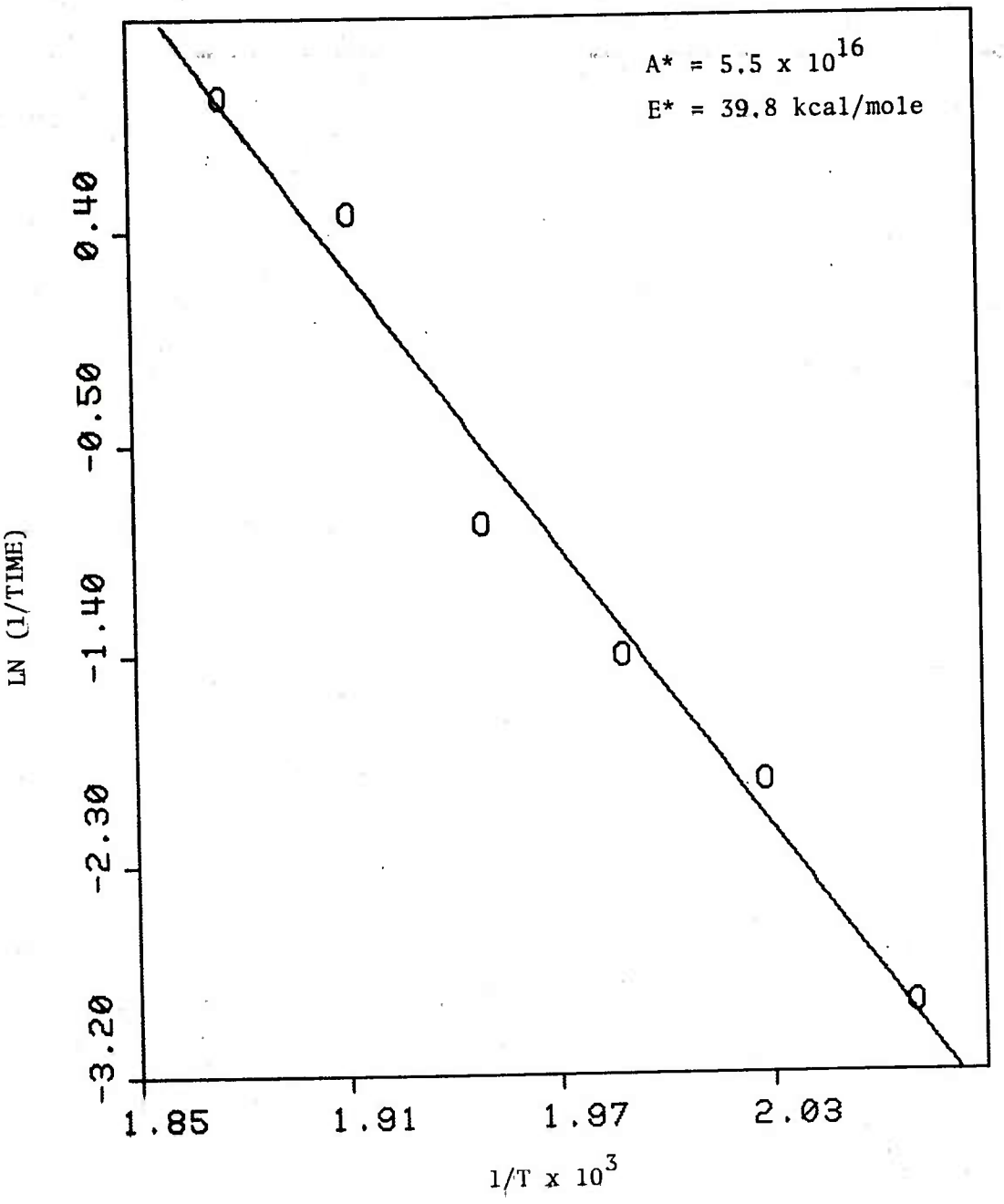

Figure 4. Arrhenius Plot for High Limit Data

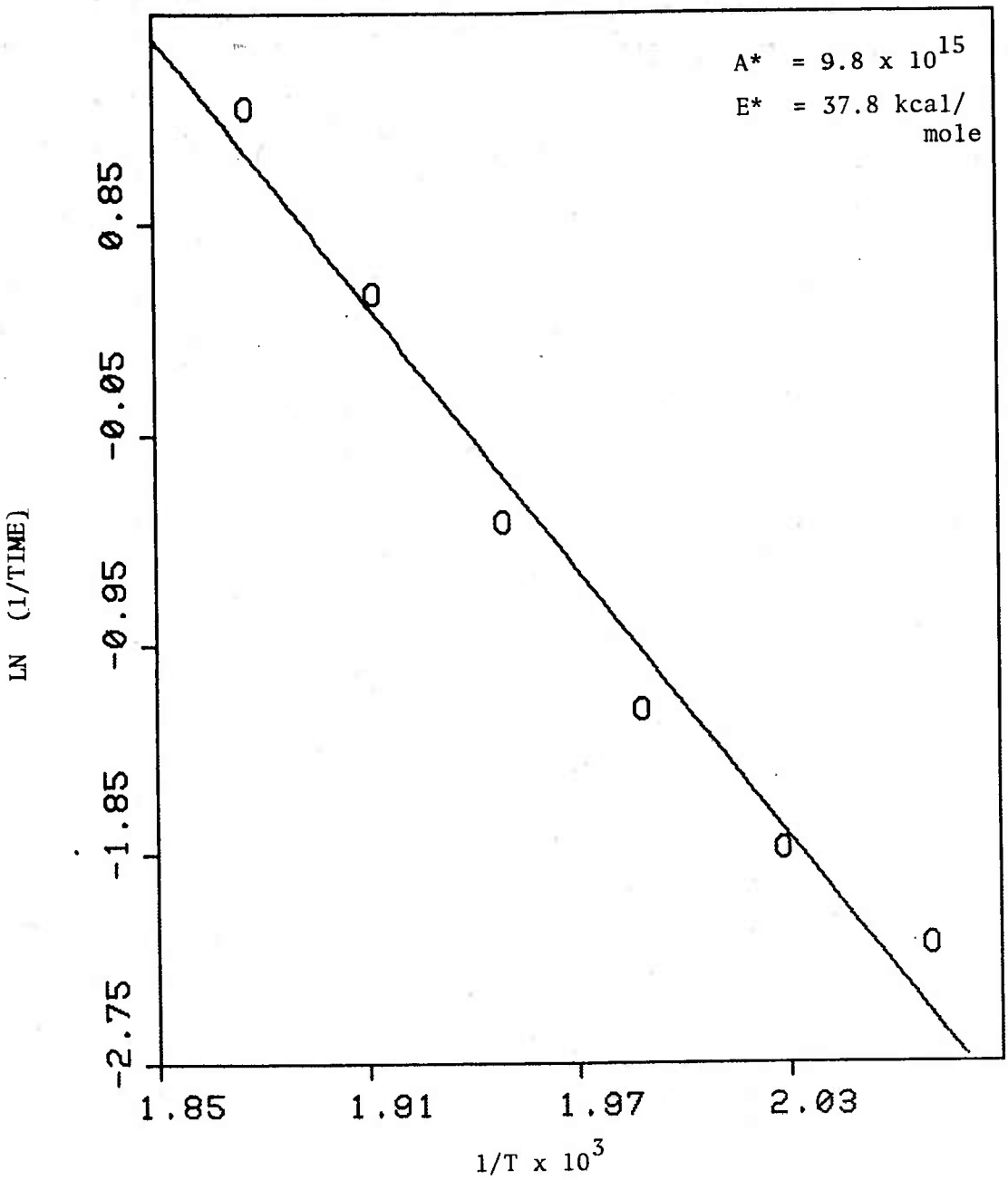

Figure 5. Arrhenius Plot for Low Limit Data

which give experimental activation energies of 37.8 kcal/mole for the lower limit and 39.8 kcal/mole for the higher limit. It is likely that the same chemical reactions are controlling at both limits, and thus the difference in activation energies is a measure of the variability in the efficiency of energy transfer in this experiment.

B. Effect of Contact Area and Geometry

To evaluate the effect of contact area and geometry, samples were run at 240 and 250°C in Test Configuration 2. These results are listed in Tables A-VII and A-VIII, respectively. Table V shows the variations in high-low limits for the two test configurations. The low limits are increased somewhat with side contact, but the high limits are variably affected. For the 6.35-mm diameter grain used in the bulk of these studies, the effect of end versus side contact does not appear to have a significant impact on the thermal ignition limits.

Table V. Comparison of High/Low Limits Between Test Configurations

Test Configuration	Temp (°C)	Time (s) Lower Limit	Time (s) Higher Limit
1	240	1.538	2.329
2	240	1.956	2.015
1	250	0.574	0.621
2	250	0.585	0.670

C. Effect of Grain Diameter

The effect of grain diameter on the ignition limit was determined. The data are given in Tables A-IX and A-X where 2.5-mm diameter samples were tested at 250°C. If a comparison is made between the two diameters in Configuration 1, the high and low limits are increased by 27 and 64 percent respectively for the smaller diameter. In Configuration 2, the difference between diameters is less than 10 percent with the low limit decreased and the high limit increased for the smaller diameter.

Table VI. Comparison of High/Low Limit Data at 250°C for Two Diameters

Test Configuration	Grain Diameter (mm)	Time (s) Lower Limit	Time (s) Higher Limit
1	6.35	0.574	0.621
2	6.35	0.585	0.670
1	2.54	0.728	1.018
2	2.54	0.541	0.733

In Configuration 1, the contact area for the 2.54-mm diameter

grain is one sixth that of the 6.35-mm diameter grain, and the perimeter to contact area ratio is 2.5 times larger for the smaller grain. This should result in significantly larger convective heat losses from the smaller grain, making it more difficult to ignite. This is reflected by the increase in the high and low limits and the increased spread between these limits for the smaller diamater grains. Due to the tangential contact of the samples with the heated surface in Configuration 2, the difference in contact area and exposed perimeter between the two grains is small, and results in the smaller differences observed in high and low limits between the two grains.

D. Effect of Contact Pressure

The method used by investigators at PTA, placing the sample (under its own weight) on the hot surface and measuring the time to ignition, was followed at 210, 240, and 250°C. The results are in Table VII.

Table VII. Summary of "No-Force Applied" Data

Temperature (°C)	Test Configuration	Average Time To Ignition (s)	Notes
210	3	---	1
210	4	---	1
240	3	63.5	2
240	4	63.5	2
250	3	41.5	
250	4	41.0	

Note 1. No ignition occurred up to 10 minutes; merely softening, wisps of smoke, and bubbling.

Note 2. When held very lightly with forceps (just enough force to prevent sample movement) average time to ignition for Configuration 3 was 21 seconds and for Configuration 4, 13 seconds.

The reactions of the samples when laid directly on the hot plate were rather interesting. Those samples placed on the cut ends "danced around", emitted wisps of smoke, and bubbles formed at the edges until ignition occurred. Samples placed on their sides rolled aimlessly all over the hot surface. The movement of these samples can best be explained by the "jet" action of the decomposition gases evolved. Because of this "dancing" movement, the probability of close contact, necessary for efficient conductive heat transfer, was diminished considerably. The large times to ignition for these experiments, compared to the data obtained with the ignition test device, underline the importance of contact pressure in determining heat transfer and therefore ignition.

IV. SUMMARY

The results of these experiments have shown that the time to thermal ignition of M30 propellant in contact with a heated metal surface follows an Arrhenius relationship. At a given temperature, ignition occurs over a time range between a low and high limit. This range decreases with increasing surface temperature. It is apparently the result of variations in the competition between heat transfer to the sample from the hot surface and heat losses to the surroundings. This is demonstrated by the effects of contact area on the ignition times (see above).

The contact pressure between a propellant grain and a heated surface has a profound effect on the time to cookoff at a given temperature. This can be seen by comparing the data in Table IV from the cookoff test apparatus with that from the "hot plate" method shown in Table VII. In the former experiment, the contact pressure of the spring (about 0.29 MPa or 42 psi) results in good contact between the sample and the heat source. Better heat transfer and therefore shorter times to ignition result.

Barsh et al.[4] in their studies of the linear pyrolysis of several organic solids such as polymethylmethacrylate found that the rate of reaction increased with contact pressure to a limit whereafter the rate was constant. A still higher pressure limit was exhibited beyond which deformation of the material occurred. The dependence of rate upon contact pressure was attributed to heat transfer effects. These results directly support the observed differences between reaction rates (times to ignition) from the cookoff apparatus and "hot plate" methods.

Chaiken and Cheselske[5] utilized the linear pyrolysis technique of Barsh et al. to study the thermal decomposition of RDX, TNT, PETN, and Tetryl. At temperatures above their isothermal "explosion temperature", these materials were observed to melt and flow away from the heated surface. The authors postulated that heat losses from the contact surface due to the melt and flow process were responsible for the lack of a thermal ignition. This phenomena was also observed with M30 using the cookoff apparatus at surface temperatures below 210°C (see above).

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[4] *M.K. Barsh, W.H. Anderson, K.W. Bills, G. Moe, and R.D. Schultz, Rev. Sci. Instr., 29 392 (1958).*

[5] *R.F. Chaiken and F.J. Cheselake, J. Chem. Phys., 43, 3228 (1965)*

This explanation is also supported by the results of Cantrell[6] in his study of the gas-film effects in the linear pyrolysis of solids. He found that there was a significant temperature gradient across the gas film which is formed by the gaseous decomposition products between the pyrolyzing surface and the heated source. This of course means that the temperature of the decomposing surface is less than that of the heat source in all the experiments discussed above. It would be particularly significant where a low contact pressure would allow a relatively thick gas film to form.

The foregoing provides a reasonable explanation for the discrepancies between the experimental data of Frey, et al.[1] and the hot plate data[2]. In the former tests, the grains in contact with the heated surface were under the weight of the propellant charge, resulting in a contact pressure similar to those used in the cookoff test apparatus used herein.

Frey[1] has cited the thermal explosion work of Baum et al.[7] and Catalano et al.[8] as possible explanation of these discrepancies. These authors have found that the reaction products from the thermal decomposition of explosives, when held in close contact to the reacting surface, can accelerate further reaction. Such close contact would be likely in the closed system of the cartridge cases of Frey but are not likely in the experimental set up of the cookoff apparatus where the decomposition products are readily lost to the atmosphere. This, together with the fact that no ignitions were observed below 210°C in the present work, have led Frey to discount the contact pressure effect from playing a significant role in the cartridge case cookoff process.

It should be noted that M30 will undergo ignition at temperatures of 177 to 210°C in dynamic TGA experiments where the constant flow of Argon (300 ml/min) would seem to severely inhibit the role of decomposition products in contributing to the reaction rate leading to ignition[9]. This lower ignition temperature is due in part to the slower heating rates of these experiments (10 to 100°C/min) and the low heat loss from the sample to the atmosphere (which is essentially at the same temperature).

It is very likely that both heat transfer (contact pressure) and acceleration of the decomposition process by reaction products mechanisms are operant in cartridge case cookoff experiments. However, it is the opinion of the present authors, that in view of the available information, the former mechanism is dominant.

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[6] *R.H. Cantrell, AIAAJ, 1, 1544 (1963)*

[7] *F.A. Baum and L.A. Shipitain, "Thermal Explosion at Elevated Hydrostatic Pressure," Fizika Goreniya i Vzryva, 2, 105 (1966)*

[8] *E. Catalano, R. McQuire, E. Lee, E. Wrenn, D. Omellas, and J. Walton, "The Thermal Decomposition and Reaction of Confined Explosives," Sixth Symposium on Detonation, San Diego, California, August 1976*

[9] *J.J. Rocchio, H.J. Reeves, and I.W. May, "Low Vulnerability Ammunition - Initial Feasibility Studies," Ballistic Research Laboratories, MR 2520, August 1975.* (AD #B006854L)

On the basis of the foregoing discussion, it would be useful to evaluate the application of the data from the present study to the prediction of cookoff in heated cartridge cases. In Table VIII, some of the experimental data of Frey[1], case surface temperature measured at cookoff and time elapsed from application of heat to cookoff, are presented. Also listed are times to cookoff calculated from the experimental case surface temperatures using the high and low limit Arrhenius parameters from the present work.

Table VIII. Calculated Times to Cookoff for M30 Propellant at Experimental Cookoff Temperatures (Times Calculated From High and Low Limit Arrhenius Parameters)

Case Surface Temperatures (°C)	Experimental Time to Cookoff (s)	Calculated Time to Cookoff (s)	
		High	Low
159	2880	2490	1360
168	1278	997	554
170	2100	787	456
183	91	217	134
183	206	217	134
185	125	179	112
186	65	163	102
197	89	59	39
214	68	13	9
219	113	9	6

Considering the scatter in the experimental data, the calculated values are remarkably similar. This is shown graphically in Figure 6 where the PTA hot plate data are also plotted. The extrapolation of the Arrhenius relations into a lower temperature regime where ignition was not observed with the cookoff apparatus is warranted because convective heat losses should be much lower in the tightly packed, fairly uniformly heated cartridge case.

This comparison suggests that the Arrhenius parameters from the present work provide a more accurate predictive capability for cartridge case cook-off than do the PTA hot plate data. An area where this could provide a direct improvement is in the model of Stansbury and Budka[10].

[10] *LeRoy Stansbury, Jr. and Alfred J. Budka, "A Mathematical Model for Design - Evaluation of Vented Ammunition Boxes," Ballistic Research Laboratories MR 2590, February 1976.* (AD #B009785L)

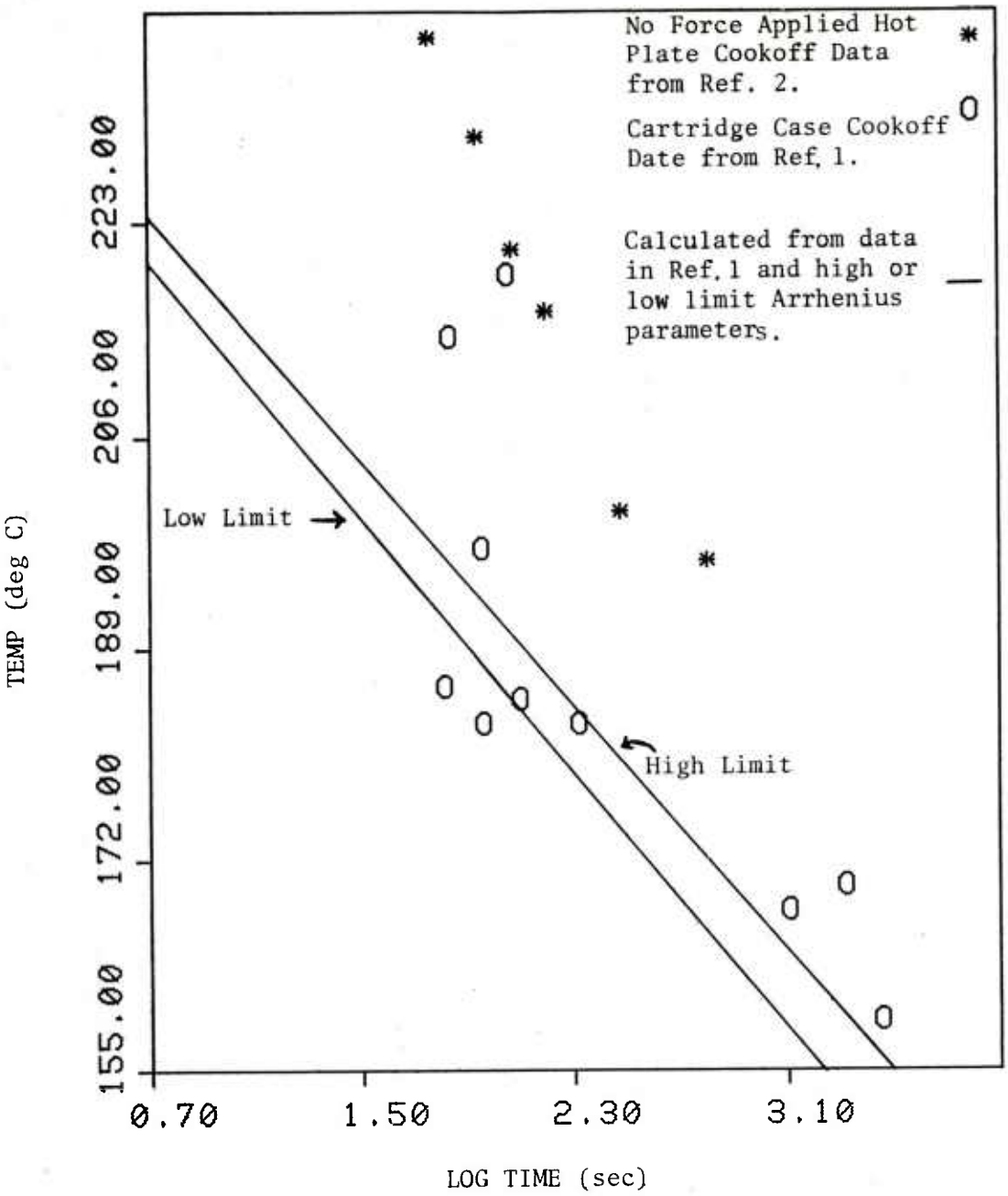

Figure 6. Comparison of Experimental Cartridge Case Cookoff Data with Calculated Data

for vented ammunition compartment design and evaluation. In this model, the PTA hot plate (temperature and time to cookoff) are used as the criteria for determining whether a cartridge case will cookoff if exposed to a fire in an ammunition compartment. As reported, this model will not allow a cartridge case to cookoff if a) the case temperature is less than 187°C (460°K) or b) the time a case is at a given temperature is less than the time required for cookoff on the hot plate at the same temperature. There are two problems with these criteria. First, the data of Frey has shown that cookoff can occur below 187°C.[1] Secondly, the present work and Frey have shown cookoff can occur much faster than would be predicted from the hot plate data. The criteria might therefore lead to an over optimistic performance prediction for a given ammunition compartment design. The Arrhenius parameters, particularly the high limit data, could directly replace these criteria thus providing a more realistic predictive capability.

V. CONCLUSIONS AND RECOMMENDATIONS

The Arrhenius parameters for the high and low limit data derived in the present work provide a reasonable predictive capability for cookoff in heated cartridge cases. The principle factor contributing to the difference in the results of Frey et al.[1] and the PTA hot plate data[2] is the better heat transfer in the former approach with possibly a lesser role played by the confined reaction products. The cookoff criteria in the model of Stansbury and Budka[10] for evaluation of ammunition compartment designs should be updated to utilize the experimental data of Frey and the present report. The present technique provides a useful approach to quantifying the cookoff susceptibility of propellants.

While the results herein illustrate the effects of temperature, contact pressure, and contact geometry on cookoff of single propellant grains, there are several aspects of the problem which should be investigated further. These include the effect of propellant composition, the atmosphere and pressure surrounding the propellant, multiple grains, and dynamic heating effects. Further investigations in these areas should make possible a useful laboratory technique for determining the susceptibility of propellants to cookoff. The final step would be the derivation of a predictive model for use in ammunition compartment and vehicle design.

ACKNOWLEDGEMENT

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1 Robert B. Frey, et al, "Pressure Measurements in Lightly Confined M456 Cartridge Cases After Primer and Cookoff Ignition," Ballistic Research Laboratory Memorandum Report No. 2764, June 1977. (AD #B020522L)

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3 Richard C. Strittmater and Hughes E. Holmes, "Hot Plate Flammability Tests," Ballistic Research Laboratories Memorandum Report No. 2292, May 1973 (AD #762149).

4 M.K. Barsh, W.H. Anderson, K.W. Bills, G. Moe, and R.D. Schultz, Rev. Sci. Instr., 29, 392 (1958).

5 R.F. Chaiken and F.J. Cheselake, J. Chem. Phys., 43, 3228 (1965).

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9 J.J. Rocchio, H.J. Reeves, and I.W. May, "Low Vulnerability Ammunition - Initial Feasibility Studies," Ballistic Research Laboratories, MR 2520. (AD #B006854L)

10 LeRoy Stansbury, Jr. and Alfred J. Budka, "A Mathematical Model for Design - Evaluation of Vented Ammunition Boxes, " Ballistic Research Laboratories MR 2590, February 1976. (AD #B009785L)

APPENDIX A. M30 Test Data

Table A-I. M30 Test Data at 210°C and Test Configuration 1 for Lot PA-63557

Test No.	Time (s)	GO	NO GO	Note
1	5.276		X	1B
2	5.910		X	1B
3	6.656		X	1B
4	8.402		X	1B
5	8.667		X	1B
6	9.051		X	1B
7	9.400		X	1A
8	9.409	X		2A
9	9.421		X	1B
10	9.439	X		2A
11	9.534	X		2A
12	9.782	X		2A
13	9.802	X		2A
14	9.936		X	1A
15	10.190		X	1B
16	10.224	X		2A
17	10.600	X		2A
18	10.986	X		2A
19	11.880		X	1B
20	12.013	X		2A
21	12.404		X	1B
22	12.678	X		2A
23	12.926	X		2A
24	13.132	X		2A
25	13.356	X		2A
26	14.001		X	1C
27	14.458	X		2A
28	14.733	X		2B
29	15.552		X	1C
30	16.090	X		2B
31	16.496		X	1C
32	17.168	X		2A
33	17.303	X		2A
34	17.550	X		2A
35	17.561		X	1C
36	18.256	X		2A
37	19.602	X		2A
38	19.775	X		2A

Table A-II. M30 Test Data at 220°C and Test Configuration 1 for Lot PA-63557

Test No.	Time (s)	GO	NO GO	Note
1	6.111		X	1A
2	6.181		X	1A
3	6.235		X	1A
4	6.257		X	1A
5	6.387	X		2A
6	6.388	X		2A
7	6.502		X	1A
8	6.640		X	1B
9	6.733		X	1A
10	6.840	X		2A
11	6.998	X		2A
12	7.045		X	1A
13	7.045	X		2B
14	7.497	X		2A
15	7.789	X		2A

Table A-III. M30 Test Data at 230°C and Test Configuration 1 for Lot PA-63557

Test No.	Time (s)	GO	NO GO	Note
1	3.048		X	1A
2	3.194		X	1A
3	3.422		X	1A
4	3.466	X		2A
5	3.522		X	1B
6	3.562		X	1A
7	3.727		X	1B
8	3.813	X		2A
9	3.874	X		2A
10	3.884	X		2A
11	3.926		X	1A
12	4.111	X		2A
13	4.150	X		2A
14	4.194	X		2A
15	5.283	X		2A

Table A-IV. M30 Test Data at 240°C and Test Configuration 1 for Lot PA-63557

Test No.	Time (s)	GO	NO GO	Note
1	1.237		X	1A
2	1.338		X	1A
3	1.457		X	1A
4	1.503		X	1A
5	1.505		X	1A
6	1.530		X	1A
7	1.538		X	1A
8	1.546	X		2A
9	1.571	X		2A
10	1.575		X	1A
11	1.577		X	1B
12	1.649		X	1A
13	1.664	X		2A
14	1.691	X		2A
15	1.697		X	1A
16	1.700		X	1B
17	1.762	X		2A
18	1.895		X	1A
19	1.915		X	1A
20	1.933	X		2A
21	1.940		X	1A
22	1.975	X		2A
23	1.984		X	1A
24	2.085	X		2A
25	2.129	X		2A
26	2.134	X		2A
27	2.136		X	1A
28	2.329	X		2A
29	2.453	X		2A
30	2.621	X		2A

Table A-V. M30 Test Data at 250°C and Test Configuration 1 for Lot PA-63557

Test No.	Time (s)	GO	NO GO	Note
1	0.550		X	1A
2	0.561		X	1A
3	0.569		X	1A
4	0.572		X	1A
5	0.574		X	1A
6	0.586	X		2B
7	0.593	X		2B
8	0.600		X	1A
9	0.600	X		2B
10	0.606		X	1B
11	0.617	X		2A
12	0.620		X	1B
13	0.621	X		2A
14	0.621	X		2A
15	0.642	X		2B

Table A-VI. M30 Test Data at 260°C and Test Configuration 1 for Lot PA-63557

Test No.	Time (s)	GO	NO GO	Note
1	0.197		X	1A
2	0.252		X	1A
3	0.260		X	1A
4	0.262	X		2A
5	0.265		X	1A
6	0.290		X	1A
7	0.297		X	1A
8	0.300		X	1A
9	0.314		X	1A
10	0.322		X	1B
11	0.328		X	1A
12	0.330		X	1D
13	0.332	X		2B
14	0.345	X		2A
15	0.345		X	1A
16	0.346		X	1A
17	0.350		X	1A
18	0.351		X	1A
19	0.359	X		2A
20	0.361		X	1A
21	0.362	X		2A
22	0.371		X	1A
23	0.373		X	1A
24	0.375	X		2A
25	0.376	X		2A
26	0.377	X		2A
27	0.377	X		2A
28	0.378		X	1A
29	0.378	X		2A
30	0.447	X		2A

Table A-VII. M30 Test Data at 240°C and Test Configuration 2 for Lot PA-63557

Test No.	Time (s)	GO	NO GO	Note
1	1.892		X	1A
2	1.911		X	1A
3	1.922		X	1A
4	1.955		X	1A
5	1.956		X	1A
6	1.957	X		2A
7	1.963	X		2A
8	1.987	X		2A
9	1.998		X	1A
10	2.015	X		2A
11	2.052	X		2A
12	2.072	X		2A
13	2.080	X		2A
14	2.136	X		2A
15	2.616	X		2A

Table A-VIII. M30 Test Data at 250°C and Test Configuration 2 for Lot PA-63557

Test No.	Time (s)	GO	NO GO	Note
1	0.487		X	1A
2	0.568		X	1A
3	0.568		X	1A
4	0.582		X	1A
5	0.585		X	1A
6	0.586	X		2A
7	0.586	X		2A
8	0.604		X	1A
9	0.620		X	1A
10	0.621		X	1A
11	0.630		X	1A
12	0.642	X		2A
13	0.645		X	1A
14	0.651		X	1A
15	0.664		X	1A
16	0.670	X		2A
17	0.671	X		2A
18	0.703	X		2A
19	0.704	X		2A
20	0.739	X		2A
21	0.797	X		2A

Table A-IX. M30 Test Data at 250°C and Test Configuration 1 for Lot RAD-E31

Test No.	Time (s)	GO	NO GO	Note
1	0.569		X	1A
2	0.611		X	1D
3	0.639		X	1D
4	0.728		X	1D
5	0.889	X		2A
6	0.914		X	1D
7	0.915		X	1D
8	0.928		X	1D
9	0.998		X	1D
10	1.018	X		2A
11	1.094	X		2A
12	1.171	X		2A
13	1.183	X		2A
14	1.278	X		2A
15	1.299	X		2A

Table A-X. M30 Test Data at 250°C and Test Configuration 2 for Lot RAD-E31

Test No.	Time (s)	GO	NO GO	Note
1	0.526		X	1A
2	0.541		X	1A
3	0.572	X		2A
4	0.575		X	1A
5	0.577	X		2A
6	0.578		X	1A
7	0.590		X	1A
8	0.605		X	1A
9	0.622		X	1A
10	0.624	X		2A
11	0.643	X		2A
12	0.645		X	1A
13	0.664		X	1A
14	0.733	X		2A
15	0.740	X		2A
16	0.749	X		2A
17	0.824	X		2A

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